Direct Numerical Simulation of turbulent natural convection flow at high Rayleigh numbers in a realistic differentially heated cavity

L.Cadet¹, A.Sergent², S.Xin³, D.Saury⁴ and P.Joubert¹

¹ LaSIE, Université de La Rochelle, F-17042 La Rochelle cedex, France
² LIMSI-CNRS, BP 133, F-91403 Orsay cedex, France
³ CETHIL, INSA-Lyon, UMR5008, 20 Av., A. Einstein, F-69621 Villeurbanne Cedex, France
⁴ PRIMME, ENSMA, BP 30179, F-86962 Futuroscope Chasseneuil cedex, France

Key Words: Direct Numerical Simulation, Turbulent Natural Convection, Experimental Data

Turbulent natural convection flows are present in many practical configurations, for example leaving or technical rooms, double-skin façade buildings... A better understanding of the involved flow is necessary to provide reference results and improve the accuracy of reduced models used in the design process or in the performance estimate of buildings or industrial processes.

Buoyancy-induced cavity flows have been widely investigated for the last decades due to the contrast between their apparent simplicity, reflected by the conservation of symmetries and the restricted domain size, and the complexity of the flow structure (thin transitional boundary, gravity waves, recirculation regions) or the involved physical mechanisms, which result from the strong coupling between the flow and the temperature field through the heat transfers. Particularly recent studies have demonstrated the major influence of radiative transfer on these flows [2],[3]. However, performing direct numerical simulations for typical Rayleigh numbers (Ra~10¹²) of the building industry remains strongly challenging [4],[5].

In this paper, we consider an experimental set-up located at the PPRIME Institute. It is an air-filled differentially heated cavity (3.81 m high, 1 m wide, 0.81 m deep), for which temperature and velocity databases are available at Ra equal to 4.10¹⁰ [1]. We present DNS results at Ra= 4.10¹⁰. This DNS is based on a finite volume approach and overcomes the wall radiation heat transfer by using the temperature experimental measurements as Dirichlet boundary conditions at wall, following the methodology of [2]. DNS results and experimental database will be analyzed regarding the heat transfers at wall as well as their influence on velocity and turbulent fields. First our DNS approach will be validated at a slightly lower Ra by comparison with spectral DNS results obtained from a full convection-conduction-surface radiation coupling, approach previously developed by Xin & al. [3]. Both these DNS use HPC techniques as hybrid parallel computing (OpenMP/MPI) and domain decomposition techniques.

REFERENCES


[2]A. Sergent, P. Joubert, S. Xin, P. Le Quéré, Resolving the stratification discrepancy of...

